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Supplementary Article

Performance Analysis of Resilient FTTH Architecture with Protection Mechanism

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Abstract

Fiber-To-The-Home [FTTH] is an alternate technology for broadband access networks. Passive optical network (PON) is considered the most promising solution due to the relatively low deployment cost. Current time division multiplexing [TDM] PON architectures are economically feasible, are band limited. The WDM PONs currently available offers enough bandwidth for the present and also for future multimedia broadband services. The purpose of this paper is to simulate resilient access network architecture with a cable route protection function based on hybrid wavelength division multiplexing and time division multiplexing passive optical network (WDM/TDM-PON) systems. Hybrid WDM-TDM PON combines the advanced features of both TDM PON and WDM PON. The reuse of existing optical fiber cable networks allows the introduction of duplicate routes for the shared portions of PONs by using a few optical fiber cables with simple structures. In this work, the hybrid WDM/TDM PON based Ladder network is simulated and the transmission characteristics evaluated. Simulation is done by using Optsim ver.5.3.

Keywords: Time Division Multiplexing, WDM-TDM, Hybrid, Passive Optical Network.

1. Introduction

FTTH is being subjected to technological advance providing enormous band width and long reach offering Triple Play services (data, voice, and video) on a single fiber. FTTH is the best solution for providing add-on services such as Video on demand, Online Gaming and High Definition Television (HDTV). The number of users demanding high bandwidth continues to increase at a rapid pace. Consequently, many service providers are planning networks capable of offering 50 Mbps, 100 Mbps, or higher bandwidth per customer. In contrast to many existing broadband technologies, such as Digital Subscriber Line (DSL) and wireless access, fiber access can easily fulfill such band width as per customer requirements, with capability of offering higher capacity in future.

Several fiber access network architectures have been developed, such as Point To Point (P2P), Active Optical Network (AON) and Passive Optical Network (PON). Furthermore, there are three main types of PONs utilizing different resource sharing technologies TDM-PON, WDM-PON. Presently TDM-PON, A/B-PON, E-PON, and G-PON are well known and already playing a key role in broadband access network services. However, it is quite likely that the existing TDM-PONs today will not be commensurate with the bandwidth-exhausting multimedia services like IP-television, HD-quality VOD expected shortly. Besides, TDM-PONs are not economical from the network investment point of view. In other words, TDM-PONs has not successfully taken advantage of the infinite optical fiber bandwidth. While WDM-PON currently offers enough bandwidth for the present and future

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multimedia broadband services fully utilizing the optical fiber bandwidth, due to lack of flexibility WDM PONs wastes bandwidth. This aspect led to utilisation hybrid WDM/TDM PON scheme in this analysis.

On the other hand, fault management in communication networks become increasingly significant due to the demand for a reliable service delivery. The fiber access networks without any protection have poor reliability. Therefore this necessitates some type of protection to increase reliability and availability of such networks. Adding redundant components and systems will improve the network reliability. PON protection types were defined in ITU-T. G983.1, in which network types are characterized on the basis of redundant paths added on the networks. The present protection designs have not been cost effective solutions, requiring an economical architecture using existing network architectures and components. The important factors are operational, maintenance costs, fulfilling of future band width demands and flexible scalable architecture. The proposed technology should also provide for improvements and replacements for future network components.

This paper proposes new resilient access network architecture based on ladder network architecture using hybrid WDM/TDM PON. A hybrid WDM/TDM PON system is an important candidate for Next Generation Optical Access (NGOA) networks. In this hybrid WDM/TDM PON, introducing a WDM dimension on the top of a TDM PON system combines the increased capacity delivered by WDM and the inherent capacity sharing of a TDM PON. This network provides a splitting ratio up to 1:512.

The ladder and grid structures are constructed by inserting bypass cable routes and duplicated optical paths are in the shared parts of PONs. By using hybrid WDM/TDM PON helps to reduce volume of required fiber and also helps to use simple optical components. The protection mechanism is implemented by changing the wavelengths of the WDM transmitters in the Optical Line Terminal (OLT) and Optical Network Unit (ONU) and there by conserves the wavelength resources.

2. System Architecture

2.1 FTTH Architecture in Residential Area

In the initial stage of FTTH introduction capital expenditure and quick implementations are the first priorities, but the FTH penetration increases the operation and maintenance cost also increases [1]. To avoid large loss due to route failure, expensive redundant optical paths are required, which increases reliability and availability of the transmission networks. A resilient FTTH architecture in the residential area is shown in the Figure 1. It has a tree and branch structure. Optical fiber cables are installed between the OLT in CO and the ONU at customer premises. Here 'P' is the total number of original cable routes and 'Q' is the number of drop areas per cable route. Then total number of drop areas is 'PQ'. Optical fibers except for those in drop and in house area are usually shared among 8–32 users.

One way to improve increase reliability of such a network is to build redundant paths by connecting adjacent cable routes with optical fibers and thereby reused the existing optical fibers in maximum possible extend. But, in practical point of view, it is not realistic to duplicate cable routes in drop and in house sections. So in this work, use redundant optical fibers that duplicate the shared parts of the PON between the OLT and each drop point.

2.2 Ladder Network

Figure 2 shows that Ladder networks are created by inserting bypass routes cable routes between existing routes. In this network TDM PONs use WDM to share most optical fibers can reduce the requirement of volume of fiber. This makes it possible to build networks with relatively low additional construction costs.

In this proposed Ladder network architecture is based on hybrid WDM/TDM PON helps to reduce this complexity. A shared networks based on WDM significantly reduces the construction cost, except for the cost of the OLT and ONUs.

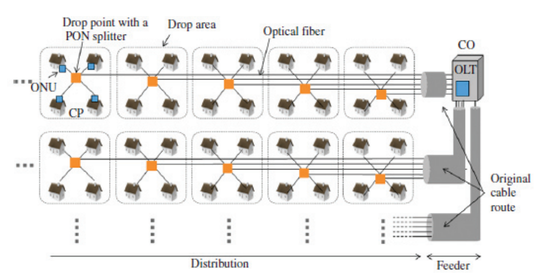

Figure 1. Basic Block Diagram.

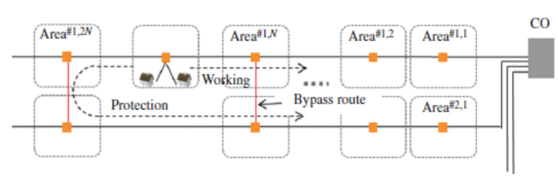

Figure 2. Block Diagram of Ladder Network.

Among many systems, WDM/TDM PON is very attractive as it offers high split ratio and saves as a large amount of feeder fibers through the use of WDM.

2.3 Principles of Ladder Network

This network is based on hybrid WDM/TDM PON and the protection mechanism is implemented by inter changing the wave lengths of upstream and downstream transmission. In this network architecture Arrayed wave guide grating (AWG) is used to transmit unicast and multicast traffic on different wavelengths to each Optical network unit. Wave length and time division multiplexing are used on the proposed network architecture. Wavelength multiplexing is used for routing purpose. In terms of network performance, the important thing is that while on a pure WDM PON there is a permanent point o point connection between the OLT and each ONU, on both hybrid network and TDM PON. The protection mechanism is described with block diagram shown in Figure 3.

Figure 3 shows the block diagrams of OLT, ONU, and optical circuits at drop points used in Ladder network. In this the bypass routes are connected per N drop areas, i.e., N=4 here. Consider P is the number of original cable routes and Q is the number of drop areas per cable route. In this WDM network the total drop areas are PQ and then 2PQ wavelengths are needed for both upstream and downstream transmissions. In the protection operation these wave lengths are interchanging conserves the wavelength resources. The OLT consists of AWG circuits and PQ pairs of transmitters (TX) and receivers (RX) in which downstream (D/S) signals with wavelengths $\lambda_S^{\#p,q}$ and $\lambda_L^{\#p,q}$ are transmitted from $TX^{\#p,q}$ to ports $I/O^{\#1}$ and $I/O^{\#2}$ respectively. In working operation, the output from $TX^{\#1,6}$

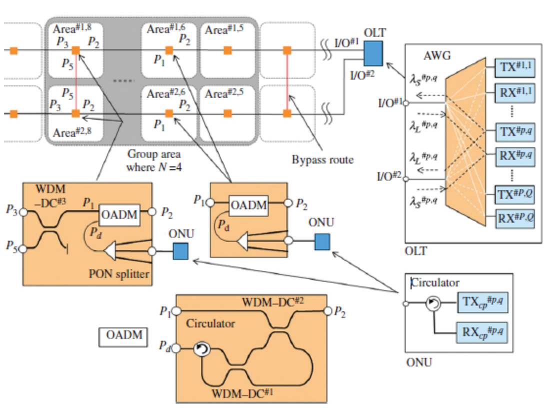

Figure 3. Block Diagram of optical waveguide circuits in the Ladder Network.

with $\lambda_S^{\#1,6}$ is connected to $I/O^{\#1}$, where as in a protection operation, the output with $\lambda_L^{\#1,6}$ is connected to $I/O^{\#}$. The ONU area$^{\#1,6}$ consists of a pair of transmitter $TX_{cp}^{\#1,6}$ and receiver $RX_{cp}^{\#1,6}$ and a circulator. The wavelengths of $TX_{cp}^{\#1,6}$ is $\lambda_L^{\#1,6}$ and $\lambda_S^{\#1,6}$ in working and protection operations, respectively. The drop point has two functions: switching to redundant optical circuits and Optical Add/Drop Multiplexing (OADM); these functions are realized by two types of optical circuit as shown in Figure 3. To clearly explain the functions of the circuits, we consider the optical signals between the OLT and the ONU in area$^{\#1,6}$. In the working operation, first a downstream optical signal with a wavelength $\lambda_S^{\#1,6}$ emitted from $TX^{\#1,6}$ travels to port $I/O^{\#1}$ through the AWG circuit and propagates in an optical fiber. Then, the optical signal is transmitted from port P2 to P1 or P3 with no coupling at WDM directional coupler (WDM–DC$^{\#2}$) and WDM–DC$^{\#3}$ in the circuits at several drop points, which are not its destination. When the optical signal reaches its destination drop point in area #1,6, it travels from port P2 to port Pd after full coupling at WDM-DC$^{\#2}$ and non coupling at WDM–DC$^{\#1}$ in OADM. The output from port Pd is equally divided at the PON splitter, and each output reaches $RX^{\#1}$, 6cpin the target ONU via the drop cable. An upstream optical signal emitted from $TX_{cp}^{\#1,6}$ with wavelength $\lambda_L^{\#1,6}$ travels from port Pd to P2 after full coupling at both WDM–DC$^{\#1}$ and WDM–DC$^{\#2}$ in OADM and then travels to $I/O^{\#1}$ of the OLT via several drop points. It is then transmitted to $RX^{\#1,6}$ by the AWG circuit.

In the protection operation, when a fault occurs somewhere along the working optical path, the wavelengths of $TX^{\#p,q}$ and $TX_{cp}^{\#1,6}$ are automatically interchanged by monitoring the received optical power in $RX^{\#p,q}$ and $RX_{cp}^{\#1,6}$, respectively. A downstream optical signal emitted from $TX^{\#1,6}$ with wavelength $\lambda_L^{\#1,6}$, which is transmitted to $I/O^{\#2}$ through the AWG circuit. As in the working operation, the optic signal passes several drop points and enters the circuit at area$^{\#2,8}$, where it travels from port P2 to P5 after noncoupling at WDM–DC$^{\#2}$ and full coupling WDM-DC$^{\#3}$. Similarly, in area $^{\#1,8}$, the optical signal travels from port P5to P2 and then in the destination area$^{\#1,6}$, it travels from port P1 to Pd after full coupling at both WDM–DC$^{\#2}$ and WDM–DC$^{\#1}$. It is finally received at $RX_{cp}^{\#1,6}$ in the target ONU. The upstream optical signal emitted from $TX_{cp}^{\#1,6}$ with wavelength, $\lambda_S^{\#1,6}$ enters OADM and travels from Pd to P1. The optical signal propagates counterclockwise along the protection path and reaches $RX^{\#1,6}$ via port $I/O^{\#2}$ at the OLT.

3. Simulation of Ladder Network

To confirm the feasibility of this network simulated their transmission characteristics using Opstsim ver.5.3. Figure 4 shows the simulation layout of network model based on hybrid WDM/TDM PON. It consists of P=2, Q=8 and 16WDMs. Here evaluated the transmission characteristic by bit error performance for downstream transmission. For transmission single mode fiber with attenuation 0.2dB/Km and length 100Km is used. The excess loss of PON splitter is 1dB. Direct modulation distributed-feedback laser (DFB-LD) source and APD photodiode with quantum efficiency 0.8 are considered. Polarization dependency of optical devices is ignored. Downlink data is transmitted at the wavelength of 1550nm in working path and 1310nm at protection path. Both the wavelengths are selected because these wavelengths window has certain advantage i.e. it is low attenuation window.

The Table 1 and Figure 5 shows the results of various BER performance of Ladder network at different average power levels. From the graph shown in Figure 6, understand that there is no more variations in the BER at −20dB and −18dB but the BER is rapidly varies after 5Gbps at average power of −24.8dB. The Figure 6 shows the BER performance at different fiber lengths. From the graph, it is understand that at the fiber lengths 30Km and 50Km no much variations in the BER. Also noticed that at 5Gbps the fiber length 100Km is suitable. At this length after 5Gbps the BER dramatically increased.

From the graph shows in Figure 7 represents the no critical difference appears in the variation of BER of

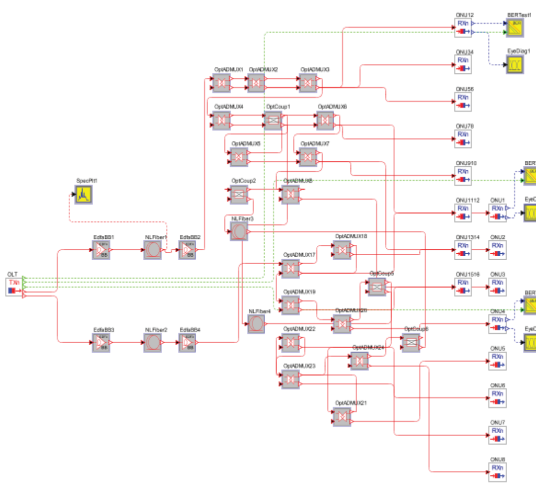

Figure 4. Simulation layout of Ladder Network.

Table 1. Results obtained from the simulation of Ladder network

Average power(-20dBm)		Average power(-24.8dBm)		Average power(-18dBm)	
Bit Rate (Gbps)	BER	Bit Rate (Gbps)	BER	Bit Rate (Gbps)	BER
1.0	5.4508e-008	1.0	1.0094e-004	1.0	1.8855e-060
2.5	9.9205e-024	2.5	1.5624e-004	2.5	2.2705e-054
5.0	2.7998e-020	5.0	3.3259e-004	5.0	5.6257e-046
10.0	5.4508e-008	10.0	8.8581e-003	10.0	8.2547e-016

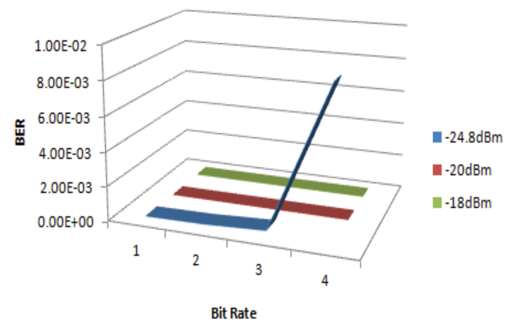

Figure 5. Graph showing the variation of BER vs. Bit rate at different power level.

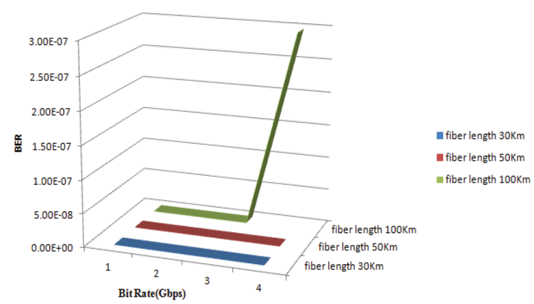

Figure 6. Graph showing the variation of BER vs. Bit rate at Fiber lengths.

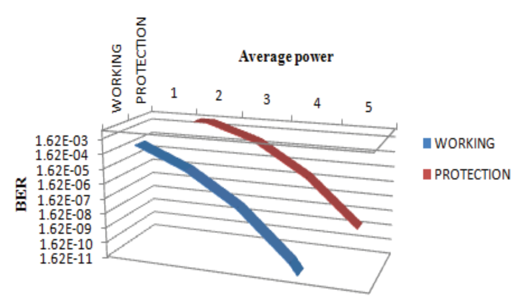

Figure 7. Graph showing the comparison of BER of working path and protection path at different power levels.

working path and protection path at different power levels. The received optical power at the BER of 10e- and 10e-12 were ¡31:3dBm and ¡24:2 dBm, respectively. These results confirm the feasibility of high receiver sensitivity and fast response wavelength switching as realized.

4. Conclusion

In this study, a resilient FTTH network architecture based on hybrid WDM/TDM PON is proposed. Ladder network with protection mechanism can be constructed with fewer optical fibers as compared to simple duplication with TDM by maximizing the use of existing fiber cables. In this network the wavelengths of upstream and downstream transmission changes helps to conserve the wave length resources. The Ladder architecture, with simple optical devices and fewer wave length resources, offers scalability and flexibility because several overlapping ladder networks with different protected areas easily covers large areas. The Ladder network in future may be a practical way of enhancing the reliability and availability of FTTH.

5. References

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